

*On the presence of Ammonia and Nitric Acid in the Sap of Plants.* By WILLIAM K. SULLIVAN.

THE discovery of the compound ammonias, and the classification of bodies by homologous series, having thrown considerable light upon the class of bodies termed amides, an ingenious view has been suggested as an extension of that of M. Gerhardt's,—that we may regard most quaternary organic bodies containing nitrogen, whether neutral acid or basic as constructed on the type of ammonia, that is, of one or several molecules of ammonia, in which the single hydrogen molecules are replaced by binary or ternary compound ones. A considerable number of amides can be produced by reactions, which are certainly better explained upon this view than by any other; but there are

Azotic bodies constructed on ammonia type.  
Many amides best explained

in this way, but the albuminous bodies not yet referable to it.

Knowledge of their constitution synonymous with chemistry of growth.

Plants receive all their nitrogen as ammonia and nitric acid.

Ammonia the probable starting point.

Function of glucose.

This view supported by products of decomposition of albuminous bodies.

many natural constituents of plants containing nitrogen, which, although connected by analogies with the amides just mentioned, we would scarcely be justified in referring to the ammonia type in the present state of our knowledge regarding them—we are indeed almost wholly ignorant of the true composition of most of them, and cannot reproduce any of them artificially. In this group of comparatively unknown and unclassified compounds is included a remarkable class of substances, found universally in plants and forming the greater part of animals, and which, to avoid perpetuating the nomenclature of a theory now generally considered inadmissible, may be distinguished as the albuminous bodies. The phenomena of growth may be said to almost consist in the production and transformation of those bodies. Hence, the discovery of their true composition is almost synonymous with that of the chemical phenomena accompanying growth.

Whatever may be the final result of the inquiries as to whether plants possess the power of assimilating nitrogen directly from the atmosphere, there can be no doubt that practically plants receive all their nitrogen in a state of combination—chiefly with hydrogen as ammonia, but also with oxygen as nitric acid. Probably in every case ammonia is the starting point of the successive agglomeration of molecules which ends in the production of the albuminous bodies, a circumstance which would, if established, confirm the view that they were constructed upon the ammonia type. It would also appear that glucose, or rather perhaps the whole class of bodies, which, for convenience sake, we might call hydrates of carbon, performs some prominent part in this ascending series of transformations.

The products of decomposition of the albuminous bodies appear to lend considerable support to this view. Thus, when they undergo spontaneous decomposition, several acids of the series homologous with acetic acid, leucine, tyrosine, ammonia, and as I have recently shown,<sup>1</sup> trimethylamine, ethylamine, etc., are formed. Heated with fused hydrate of potash, they yield the same acids, leucine, tyrosine, ammonia (traces of compound ammonias are always found in the disengaged

<sup>1</sup> Hesse, it appears, has also obtained similar results—see an account of his experiments among the *Scientific Notices*.



ammonia), and hydrogen. Distilled with sulphuric acid and deutoxide of manganese, they yield the same homologous acids and their hydurets, and also the hyduret of benzoyle; with the more energetic oxidizing mixture of sulphuric acid and bichromate of potash, the products are nearly the same, but there is also formed hydrocyanic acid and valeronitryle, or cyanide of tetryle, a body resulting from the action of hydrocyanic acid upon hyduret of valeryle.

But ammonia is not only absorbed by the roots of plants, but also sometimes exhaled by the flowers or leaves, as Chevallier, I believe, first pointed out in the case of *Chenopodium Vulvaria*; and Dessaignes has since shown that propylamine (or more probably the isomeric base, trimethylamine) accompanies the ammonia. This remarkable circumstance appears to indicate that, either a portion of the nitrogenous compounds formed from the absorbed ammonia is again decomposed, and the ammonia set free during the process of growth, or that ammonia performs other functions besides contributing to the formation of albuminous bodies. The first view seems to harmonize with the change which albuminous bodies undergo in passing into those active states in which they exert so remarkable an action upon starch, etc. It is very probable that the action of such ferments as diastase is sometimes accompanied by the production of ammonia, compound ammonias, small quantities of the acids homologous with acetic acid, and carbonic acid—that is, that the action may be considered as a kind of putrefaction. Traces of ammonia and of the acids in question are invariably found in the ordinary fermented liquors, especially when the process is carried very far. There are also many reasons for supposing that this is really the case during the germination of seeds having an endosperm.

Ammonia also exhaled by flowers, etc.

Azotic bodies decomposed during growth evolve ammonia.

Action of diastase analogous to putrefaction.

Ammonia, etc., formed by fermentation.

The nitrogen of active substances may not always be separated in these transformations as ammonia: it is quite possible that in some plants it may be separated in an uncombined condition. Saussure, indeed, showed that plants evolved nitrogen as well as oxygen when exposed to sunlight. Some, as Boussingault, consider that the nitrogen thus evolved is derived from that contained in the water absorbed by the roots, but Draper concludes from his experiments, that it is derived from an azotized substance acting as a ferment. Or it may be separated as

Nitrogen of active bodies evolved. Experiments of Saussure, Boussingault, Draper.

It may be separated as a fixed base, a fixed base, a fixed base, and may be deposited in the bark or seeds, and again take part in further transformations. It certainly does appear as if several of the organic bases found in plants should be considered merely as excretions.

supported by ammonia found in barks.

This view seems to be supported by the interesting circumstance that ammonia appears to always accompany vegetable alkalies in barks. Thus Reichardt<sup>2</sup> found 0.137 of ammonia (calculated as  $\text{NH}_4\text{O}$ ) in the dried cinchona bark of *Calysaya plana*, 0.123 in that of *Calysaya convoluta*, 0.086 in young weak pieces of Huanco cinchona 0.100 in the bark of *Cinchona ovata*, var. *erythroderma* (Wedell), and in a specimen of bark from *Cinchona cordifolia*, 0.266, or more than one-fourth of the whole organic bases present. Reichel<sup>3</sup> found in old strong pieces of Huanco bark, 0.070 of ammonia ( $\text{NH}_3$ ), and in the bark of the stem of *Cinchona Condaminea*, var. *lancifolia*, 0.210, or nearly one-third of the whole amount of quinine cinchonine and quinidine found in the same specimen; in the bark of the stems of the same species, he found 0.220, and in that of the twigs, 0.153 per cent.

Nitric acid may be formed in plants,

supported by distribution of nitrates in some plants.

There is one other form of combination in which the nitrogen may possibly present itself when it has fulfilled the functions of a ferment in plants, namely as nitric acid. I mention this singular hypothesis merely for the purpose of suggesting a line of research which cannot fail to lead to many important results, whatever may become of the hypothesis itself. To anticipate the results, which I am about to give presently, I may observe that nitrates occur in small quantities very generally in the sap of most plants, but in those plants especially which either perceptibly evolve ammonia, or which yield it along with compound ammonias when distilled with water. In such cases the nitrates are more abundant in the leaves and leaf-stalk, and in bulbous-rooted plants in the crown from which the leaves spring. The proportion of nitric acid is often so considerable in the leaves that it is difficult to suppose it wholly derived from nitrates absorbed by the roots from the soil. This difficulty appears to be increased by the circumstance that in bulbous roots, at least in those which I examined, the parts nearest the

<sup>2</sup> Chemisch-physiologische Abhandlung über die Chemischen Bestandtheile der Chinارينden von Dr. E. Reichardt. Braunschweig, 1855; also Gmelin's Handbuch, Bd. viii. S. 51 & 52.

<sup>3</sup> Ueber Chinارينden und deren Chemische Bestandtheile. Leipzig, 1856; also Gmelin's Handbuch, Bd. viii. S. 52 & 53.



fine rootlets do not contain more nitrates than the centre, but on the contrary less, and that they appear to spread downwards from the leaves. The following results show this distribution of the nitric acid in an entire plant of sugar beet weighing about 8 lbs.:—

	Per-centage of nitric acid.
1. The whole of the leaves and leaf-stalk, . . . . .	0.180
2. Upper segment of crown, . . . . .	0.220
3. Segment of bulb $\frac{1}{2}$ inch thick, cut at right angles to axis one inch below crown, . . . . .	0.060
4. Similar segment cut $2\frac{1}{2}$ inches below No. 2, . . . . .	0.040
5. Similar segment cut 3 inches below No. 3, or a little below the middle zone of root, . . . . .	0.045
6. Point of root $2\frac{1}{2}$ inches long, . . . . .	0.020

This distribution of nitrates corresponds exactly with that already pointed out for the solid matter. It is possible that some of the ammonia liberated in the leaves or existing in the sap may have been oxidized by the nascent oxygen set free in the leaves by the action of sunlight, and may thus account for the accumulation of nitrates in the leaves and crown. This nitric acid would of course be gradually removed from the leaves and again decomposed. It may of course be objected, that the nitrates absorbed from the soil accumulated in the leaves very much as other saline matter. This might no doubt explain it; but then, on the other hand, when beet is grown on land heavily manured with nitrates, they are absorbed and are found in every part of the plant, but in such excess in the bulb as sometimes to replace nearly the whole of the sugar; the accumulation in the leaves not being in a corresponding proportion. I am fully sensible that experiments such as those just given are not of that definite character which should be adduced in support of so novel an hypothesis. I did intend to make a series of experiments with plants of tobacco, different species of chenopodium, etc., so soon as I could get an opportunity; but in the meanwhile it may be worth while to put the hypothesis before chemists who may have more facilities for such experiments than I possess.

Experiments made not enough;

others to be made.

With regard to experiments of this kind I may remark, All that all plants would not necessarily give like results. Although the phenomena of germination and growth possess the same general features in all kinds of plants, they must exhibit many points of difference when different families are compared. The observations of Saus- plants do not give like results:

exam-  
ples.

sure and others upon the relative absorbent powers of plants; for saline solutions, afford us many examples of such differences. Thus Trinchinetti<sup>4</sup> found that *Mercurialis annua* and *Chenopodium viride* absorbed much saltpetre and little common salt from a solution containing both salts. On the other hand, *Satureja hortensis* and *Solanum Lycopersicum* absorb much salt and little saltpetre. *Vicia Faba* takes up much salt, while *Mercurialis annua* absorbs much chloride of ammonium from a solution of both.

Ammonia and nitric acid in every part of plants;

noticed as constituents of plants in analyses;

not frequently enough to establish general diffusion.

Such inquiry the basis of phytochemistry.

Statements

Part of the salts of ammonia and nitrates, when taken up by the roots, must begin to be transformed immediately; but it has not been ascertained to what extent the transformation proceeds before reaching the leaves. If the process be slow, then we may expect to find both ammonia and nitrates present in every part of a plant, except perhaps in the fully ripened seed. Again, if the fermentative action of albumen be in some cases accompanied by the production of ammonia, and if nitric acid can be formed by the oxidation of the latter in leaves, we have a second distinct cause for the general diffusion of ammonia and nitric acid in the juices of plants. Ammonia and nitric acid are noticed as constituents in the results of analyses of many plants, especially in those made about twenty or twenty-five years ago. In some instances the presence of the ammonia may have been owing to putrefaction or the action of reagents; but such an objection cannot be urged against the newer analyses, in which better processes were employed and most of the probable sources of error known. These isolated examples, some of them also being liable to the objection just stated, though proving that both ammonia and nitric acid exist in considerable quantity in certain plants, would not suffice to establish their diffusion in all plants. The establishment of such a fact is obviously of the greatest importance, because it must serve as the indispensable basis to all inquiries concerning the changes which take place during the growth of plants, and the influence of chemical agents upon those changes. From this point of view I undertook to collect together all the statements concerning the presence of ammonia and nitric acid in plants made up to the present time, and to exa-

<sup>4</sup> *Sulla faculta assorbente della radici*, quoted in Gmelin's Handbuch, Bd. viii.



mine a large number myself. I have combined the results of previous observers, which are more numerous than might be supposed, with the extensive series obtained by myself, in the form of a table which will be found further on, in which the plants are arranged according to the natural families. collected and new experiments made by author.

This is the place to acknowledge my obligations to Professor Rochleder's *Phytochemie*, in gathering together the results of previous experiments. Indeed, whatever of completeness the table possesses in this respect, is justly due to the assistance which his labours have afforded me.<sup>5</sup> Author's obligations to Rochleder.

Before describing the processes employed to detect the ammonia and nitric acid in the plants contained in the table, I will make a few observations upon the probable transformations which ammonia undergoes in plants, and mention some experiments which I made in connection with this subject.

Whether the ammonia found in plants be wholly derived from the soil, and therefore representing a part of the still unassimilated food, or be also in part a product of the transformations occurring during their growth, the quantity must necessarily be small and variable; it may even be that no appreciable trace could be found in one specimen of sap while abundance may be found in another. As we might naturally expect, plants grown upon rich soils or upon artificially manured land, gave more than those grown upon dry, barren soils. The position of a plant with regard to sunlight appeared to materially affect the ammonia in the sap and leaves. Thus plants which had rankly grown upon a rich soil in the shade, always seemed to contain more ammonia than those which had grown under the full influence of sunlight. Perhaps this observation would not apply to ammonia resulting from transformations of growth, and which would be chiefly found in flowers and in the descending sap in the bark. Here, the greater the energy of growth, or in other words the greater the amount of sunlight, under other Quantity of ammonia in plants small and variable; more in them on rich than on barren soils, in the shade than in sunshine; not applying to ammonia formed during growth.

<sup>5</sup> Professor Rochleder's work (*Phytochemie von Friedrich Rochleder, Med. Dr. and Prof.—Leipzig, verlag von Wilhelm Engelmann, 1854*), is the first systematic attempt made to connect the form of plants with their chemical composition. More recently Professor Rochleder has written the part of the eighth volume of Gmelin's *Handbuch der Chemie*, devoted to phyto-chemistry, upon the same plan. The two works supplement each other, and will, no doubt, contribute greatly to the advance of this branch of science. I regret that I had not an opportunity of using the second work in the construction of my table.

necessary conditions, the more ammonia may be formed. European grown tobacco, especially that grown in North Germany, Belgium, and the northern departments of France, contains more ammonia than that grown in tropical countries. Perhaps this increased quantity is due to unassimilated ammonia derived from the soil, while the large quantity of ammonia contained in the Cinchona barks may be derived from the transformation of albuminous bodies.

Analogous observations of others.

I am anxious that the preceding observations should be considered merely as suggestions, and not as positive opinions. Yet they derive some interest from analogous observations made from time to time by others. For example, Stenhouse found that *Cytisus scoparius* contained more of the basic substance sparteine, when grown on sandy, sunny spots, than when it luxuriantly vegetated in the shade. In like manner Pless has shown that *Erysimum alliaria* produces only oil of mustard when grown upon sunny places, but in shady places produces both oil of mustard and oil of garlic.

Associated constituents of each plant given in table. No conclusion yet deducible from these.

In the table containing the names of plants in which ammonia and nitrates have been detected, I have added a column containing the names of the acids, bases, bitter substances, etc., which are found associated in each plant. In the present state of our knowledge, no deductions of any value can be drawn from such associations, but it is obvious that we should always keep them in view in chemical experiments upon plants. But not only should we know the constituent proximate principles of a plant as a whole, but those of each organ separately; we would then be able to ascertain where particular substances were first formed, and where others ceased to be present. The difference between the composition of the ascending and descending sap should be particularly attended to.

Origin of odoriferous bodies most obscure;

Perhaps the odoriferous principles of plants are those among the proximate constituents whose origin is most obscure. They belong chiefly to the following categories: 1. volatile acids related to alcohols, aldehydes, ethers; 2. carburets of hydrogen, oxygenated substances derivable from them. The former class appears to be more frequent in flowers and fruit where the process of deoxidation is feeble. Both of them appear to be somehow connected with the transformations of azotic bodies, and may in many cases be regarded with considerable probability as the excess of carbon and hydrogen separated in the pas-

probably connected with changes of azotic bodies,



sage of one body into another, especially of those belonging to the class of amides. The circumstance that the production of many essential oils is increased in the direct rays of the sun seems to favour such a view. In the case of such a plant as *Calotropis procera*, which is odoriferous in the sunlight and odourless in the shade, the essential oil is obviously a kind of excretion.

and  
therefore  
excre-  
tions.

There can be no doubt that some azotic bodies can only be formed under the influence of sunlight, but there are others which can certainly be generated without it. Thus asparagine is perhaps more abundantly formed in darkness than in sunlight, and when so produced, appears to be rapidly transformed if the plant be exposed to light. Young plants of the vetch, for example, when grown in a dark cellar, contain a great deal of asparagine, which disappears with considerable rapidity on exposing them for a day to sunlight.

Some  
azotic  
bodies  
formed  
without  
sunlight.

The late Professor Gregory it was who first suggested, I believe, that amides are perhaps the first bodies formed in plants. The existence of a vegetable acid in the sap would fulfil the chief condition, as it would always find itself in the presence of ammonia absorbed by the roots. The amides might be of two classes,—that is, we might have amides derived from ammonia salts of organic acids by the loss of water, or in which the hydrogen of the ammonia would be replaced by an oxygen compound, and would be either neutral or acid; and others in which the hydrogen would be replaced by a carburet of hydrogen, such as the so-called compound ammonias. Both may, and no doubt are, simultaneously formed in most, if not all plants, but it is probable that the predominance of one or other class may be characteristic of some families. In seeds with endosperms, and in which none of the acids analogous to malic acid or to oxalic acid occur, it may be that the first stages of growth depend upon the production of compound ammonias. When acids of the kind mentioned are present, the formation of the other class of amides may be most prominent. Asparagine, which only occurs in plants containing malic acid, may be but the type of a number of similar bodies formed with other acids. Thus oxamide, or rather a body bearing to it the same relation that asparagine does to malamide, may fill the same functions in plants containing oxalic acid as asparagine does in those containing malic acid. I made some experiments with *Oxalis Acetosella* in order to determine whether such a

Amides  
the first  
bodies  
formed ;

might be  
of two  
classes.

Circum-  
stances  
under  
which  
each  
class  
may be  
formed.

body existed in it, but have not as yet obtained any definite results.

Other reactions which seem to show that ammonia is the starting point.

Besides the conclusions which may be drawn from the products of putrefaction and oxidation of the albuminous bodies, as already stated, other reactions seem to show that the substitution of the hydrogen molecules of ammonias by carburets of hydrogen, etc., is the process by which the azotic bodies of plants are built up. Wurtz, Rochleder, Wertheim, and Anderson, have shown that the whole, or a part, of the nitrogen of the organic bases may be separated as methylamine or similar bodies; while, on the other hand, the existence of several of these bodies in plants has been established by Dessaignes, Wittstein, Wicke, and myself. It may be that the first stage is the formation of a salt of ammonia with an organic acid, which, by loss of water, becomes an amide, and by deoxidation in the leaves, an ammonia base. If the latter class of bodies be formed in this manner in plants, we may expect to find traces of them where their presence has not hitherto been suspected. Plants growing upon natural soils must of course contain, at any given moment, but a very small portion of such bodies, even assuming their universal diffusion; a larger proportion would be found in those grown upon highly manured soils. It accordingly occurred to me that I might very largely increase the quantity, in case they are found at all, by growing some plants upon land dosed with azotic manures. With this object I divided a piece of ground into patches of two square yards, separated by deep trenches. One patch was left unmanured, and the other ten were manured with three classes of azotic manures, as follow:<sup>6</sup>

Experiments to ascertain whether compound ammonias are formed in plants.

- |  |   |  |
|--|---|--|
| I. Undecomposed animal matter, - - -         | { | 1.—112 lbs. of fresh cow's blood.                            |
|  |   | 2.—7 " of dried horse flesh.                                 |
|  |   | 3.—6 " of powdered dried sprats, and 31lbs of salted sprats. |
|  |   | 4.—Farmyard dung.  |
| II. Manures containing ready formed ammonia, | { | 5.—14 lbs. of dried night soil.                              |
|  |   | 6.—14 " of Peruvian guano.                                   |
|  |   | 7.—14 " of sulphate of ammonia.                              |
|  |   | 8.—14 " of chloride of ammonium.                             |
| III. Nitrates,                               | { | 9.—14 " nitrate of potash.                                   |
|  |   | 10.—14 " nitrate of soda.                                    |

<sup>6</sup> I owe to the kindness of Dr. Kirkpatrick, the Director of the Agricultural Department under the Commissioners of National Education, the means of making these experiments. He not only placed the piece of ground at the Model Farm, Glasnevin, at my disposal, but afforded me every other facility in his power in carrying them out. It is not



Upon the patches so manured, as well as on the unmanured patch, two varieties of beet (long red mangel wurzel and sugar beet) were grown. At the commencement of last winter they were examined for ammonia, etc. For this purpose about 15lbs. to 20lbs. of the roots were cut into thin slices and boiled with water (free from ammonia) to which a small quantity of sulphuric acid was added, until the whole was reduced to a pulpy mass; this was strained through bags and pressed; the strained decoction was then distilled, the distillate treated with hydrochloric acid and evaporated carefully to dryness. A residue was obtained from the roots grown upon each plot treated in this manner, but very variable in amount, being apparently most abundant from the blood and salts of ammonia.

Process employed to separate ammonia and bases.

The series of dried residues obtained in this way were next successively submitted to the same process of examination, as follows:—The dried mass was treated with a mixture of anhydrous ether and alcohol, which in every case dissolved a part; the insoluble part was chloride of ammonium, as was shown by a determination of the per-centage of platinum in the precipitate which it formed with chloride of platinum.

The alcoholic solution was distilled to separate the alcohol and ether, the residue was dissolved in the smallest possible quantity of water, and the solution divided into two unequal portions. A concentrated solution of chloride of gold was added to the larger portion, forming about two-thirds of the whole, by which a yellow precipitate was thrown down. The remaining one-third of the liquor was then added to the portion containing the precipitate, and the whole allowed to digest at a very gentle temperature; when perfectly cold it was filtered to separate the precipitate, a few drops of the gold solution were

---

the only occasion upon which he has shown his desire to further scientific experiments in connection with agriculture. Now that a great number of model farms are established, it is to be hoped that the public will see the importance of encouraging the carrying out of such experiments as are required to solve important questions in agriculture, and which could not be made by private means. This would be one of the most important advantages to be derived from the present agricultural organization, and would be more than equivalent for the whole sum spent in their support. I wish also to acknowledge my obligations to Mr. C. F. Patterson for the care which he devoted to the plots: indeed, without his kind assistance, I could not have made the experiments at all. I am indebted to Mr. Ritchie, of Belfast, for the greater part of the manures.

added to the filtrate, which was then set aside over sulphuric acid.

Trimethylamine

The precipitate remaining on the filter was dissolved in boiling water, and the solution set aside over sulphuric acid in the dark. In the course of a couple of days the whole or a greater part crystallized out in the form of short cube-like prisms and octohedra, having all the characters of the gold salt formed by trimethylamine. The following determinations made with salts repeatedly crystallized out of a boiling solution, from which the crystals separated on cooling, confirmed this supposition:

1.	0.125 grammes of the salt gave	0.062 grammes of gold.
8.	0.205       "       "	0.101       "       "

which correspond in 100 parts to—

	<i>calculated</i>	<i>found</i>
1. }	49.326	{ 49.600
8. }		{ 49.268

It was not found practicable to determine the exact composition of the crystals in the other cases, but there could be no doubt of their identity with those analysed.

and some other bases formed in highly manured plants.

The mother liquor filtered from the precipitate as above, and set aside in the dark over sulphuric acid, gave after some time, besides crystals of the gold salt just described, some of other gold salts, among them fine bundles of lustrous golden orange-coloured needles and small micaceous scales. The quantity was, however, so small that no further separation could be attempted. In addition to ammonia, therefore, the presence of trimethylamine was ascertained in the roots grown upon all the plots, and the existence of traces of several other bases established with certainty in those grown upon plots 1, 7, 8, 9, and with considerable certainty in most of the others.

Pastinacine, etc., probably only the same base.

It is very probable that the volatile bases which have been mentioned from time to time as occurring in several plants belong to the same class as those formed in the roots just mentioned. Among them I may specially mention pastinacine, from the parsnip, in which, by a similar process, I also found trimethylamine, cicutine, from *Cicuta virosa*; the supposed volatile alkali of *Chaerophyllum bulbosum*, etc. Another fact of considerable importance in connection with this subject is the interesting obser-



vation of Kekulé and Von Planta, of the presence of methyleconine along with conine in hemlock. From some experiments of my own, I am inclined to think that methylenicotine is also often present in tobacco.

I shall now return to the description of the processes employed to detect ammonia and nitric acid in the plants named in the subjoined table, examined by myself.

In order to determine if ammonia was present, the sap, expressed juice, infusion in cold or hot water, or decoction, as the case may be, and in some cases the flowers, young twigs, or young buds, were introduced into a small tin vessel, provided with a head and condensing-worm, and furnished with a small steam-pipe connected with a boiler. The latter was charged with water to which some lime water was added, and allowed to produce steam for some time, until half a gallon of the condensed water gave no trace of ammonia when evaporated with a few drops of hydrochloric acid, which was usually the case when about one-third of the water had been vaporised. The absence of all appreciable traces of ammonia in the steam employed having been thus secured, the steam was turned on until the volatile oils, etc., had passed over; a little baryta water, or a very dilute solution of caustic soda, was then added, and the distillate collected apart, treated with some drops of pure hydrochloric acid, and evaporated to dryness. The residue, if any, was chloride of ammonium or other volatile bases, always coloured with some organic substance; it was usually tested for ammonia in the ordinary way; but when a sufficient quantity was obtained, compound ammonias were sought for, as will be described further on. Sometimes ammonia came over with the volatile oil before the addition of the baryta water or solution of soda. Where the quantity of material was too small to admit of adopting the process just described, which was usually the case with saps, the distillation was effected in a glass retort with baryta water.

I found great difficulty in detecting a small quantity of nitric acid in a solution containing a mixture of organic substances, and still more in the determination of its amount. I sought everywhere for the description of the processes which others had followed, but with the exception of the indirect method described by Ville, I could not find one. If any have been published, they are not mentioned in any of the usually

Processes used to determine the presence of ammonia in plants.

Difficulty of determining nitrates in plants;

processes not usually described;

benefit  
from  
publica-  
tion of  
pro-  
cesses.

available sources of information. It is to be regretted that the processes employed in the proximate analysis of plants have not been more frequently described in detail, for a knowledge of those processes is necessary to enable us to understand the exact value of the results. Again, the publication of a process prevents the reinvention of it, and leads to its gradual improvement and simplification, or its substitution by a better one. Not having been able to find any, I successively devised several; but, with the exception of the one which I shall now describe, they were more or less unsuccessful. But even that which I finally adopted is very complicated and troublesome, and leaves much room for improvement. When, however, great care is taken, and the operations are not hurriedly done, very satisfactory results can be obtained. It is but right to add that, although the process be complex when we seek to isolate only a single constituent, it possesses the advantage of being readily made the basis of a process for the complete proximate analysis of plants.

Author's  
process  
for deter-  
mining  
nitrates.

The substances which may be present in the juice, infusion or decoction of plants, are: dextrine, gum, mannite, glucose, cane sugar, some of the gelatinous principles, glucosides, tannins, acids of the series which yield pyrogenous acids—malic, citric, fumaric, tartaric (also racemic or inactive tartaric acid), and aconitic acids; acids of the series homologous with acetic acid—acetic, etc., acids; lactic acid; acids homologous with oxalic acid—oxalic and succinic acids; bitter principles; colouring matters; amides—asparagine, etc.; alkalies; neutral azotized or albuminous bodies; chlorides of potassium, sodium, ammonium, etc.; sulphates of potash, soda, etc.; phosphates of potash and soda; nitrates of potash, soda, and ammonia. The organic acids will also be usually in combination with some base. All the substances just named will not, of course, occur together in any one plant, the existence of some of them in the same fluid being incompatible. Of the organic acids only one or two are usually found in the same plant, but as many as four or five may occur. As all nitrates are soluble in water, and those which are insoluble in alcohol almost invariably correspond to the salts of the organic acids present, insoluble in the same medium, the separation of the nitric acid present in the sap or juice of a plant involves the successive separation of every one of the



bodies above enumerated which may happen to be present. It is on this account that a process for the determination of the amount of nitrates in plants must necessarily be a process for the separation of all the proximate constituents of vegetables.

The sap or expressed juice, as the case may be (having been weighed, if a quantitative determination be made), is to be heated to boiling, in order to coagulate the albumen. A quantity of lime water is added to precipitate certain nitrogenous bodies not coagulated by heat, pectic, phosphoric, oxalic, etc., acids. This precipitate should be allowed to deposit, and when separated may be employed to determine the amount of the latter two acids. The sulphuric acid may also be thrown down with baryta. A stream of carbonic acid is then to be passed through the liquid to neutralize excess of lime and baryta. The liquor is then boiled, filtered, to separate carbonates of lime and baryta, and a few drops of sulphuric acid added to the liquor, again boiled, to convert any cane sugar present into glucose. Before performing this operation, the amount of deviation might be determined by the polarimeter, and again after boiling with acid, by which data for determining the amount of sugar would be obtained. The liquor boiled with acid is then carefully neutralized with baryta and made to ferment with yeast until the whole of the sugar is converted into alcohol. The fermented liquor is then distilled to remove the alcohol, the quantity of which may be employed to control the previous determination of the amount of sugar. In juices containing a very large amount of sugar and of salts of malic, etc., acids insoluble in alcohol, a portion of the salts may be precipitated during the progress of the fermentation if the liquor happen to be somewhat concentrated. This is, however, of no consequence, because they are re-dissolved according as the alcohol is removed by distillation.

The liquor remaining in the retort after the distillation is carefully evaporated to dryness in a water bath, and the dried residue treated with anhydrous alcohol (distilled off lime, and not off carbonate of potash), which dissolves mannite, acetates and lactates of potash or soda (and a trace of citrate of soda, if present), etc. This solution I shall call B.

The residue after treatment with anhydrous alcohol is then treated with perfectly neutral anhydrous ether, to

remove colouring matter, resins, fats, and any peculiar crystalline body soluble in it but insoluble in alcohol, which may be present. This solution, which I shall call C, may be employed to determine the fats, etc.

The residue of this successive treatment with alcohol and ether is dissolved in the smallest possible quantity of water, and then treated with an alcoholic solution of oxalic acid, and set aside for some time with frequent shaking; the whole of the salts present will be decomposed, and oxalates of potash and soda formed, which, being insoluble, will be precipitated. The strongest alcohol should be used to dissolve the oxalic acid, and sufficient of the solution should be added to that of the residue in water to form a mixture much stronger than ordinary spirits of wine. In solution will be found hydrochloric acid, nitric acid, and all the organic acids present. An alcoholic solution of sulphovinate of silver is then to be added, and some recently prepared oxide of silver; chloride, oxalate, malate, citrate, aconitate, tartrate, and fumarate of silver will, if present, be separated. By allowing the whole to remain together for several hours, shaking the flask from time to time, and finally plunging it into hot water for some minutes, the sulphovinic acid set free will be neutralized by the dissolution of the oxide of silver, and there will now remain in solution only nitrate of silver and the excess of sulphovinate of silver. The solution is separated from insoluble compounds by decantation, and the alcohol distilled off; the residue left in the retort is boiled with water to which baryta is added, by which the whole of the silver is thrown down, and the sulphovinic acid decomposed, the sulphuric acid being precipitated by the baryta according as it is set free. The excess of baryta may then be removed by passing a stream of carbonic acid through the liquid, and then boiling it. The liquid, filtered and evaporated to dryness, yields nitrate of baryta.

Solution B may be employed for the determination of lactic and acetic acids, mannite, etc., if present. Solution C and the silver salts of organic acids may likewise be employed for the determination of the different bodies contained in them.



*List of Plants in which the presence of Ammonia and Nitric Acid has been observed.*

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
RANUNCULACEÆ. Helleborus niger, ...	Root—Feneulle & Capron	...	Helleborine (base ?), gallic acid. ?
MENISPERMACEÆ. Jateorrhiza palmata (cocculus palmatus) (calumba root)	..	Root — Boederker	Columbic acid, probably malic acid. Colombine (bitter, non-nitrogenous) Berberine (base)
Animirta cocculus (A. paniculata) (fruit the cocculus indicus)	..	Seeds — Pelletier & Couerbe	Malic acid, menispermine (base) paramenispermine, picrotoxine (non-nitrogenous), fat oil.
CRUCIFERÆ. Nasturtium officinale—Watercress	...	...	Yields a sulphur oil.
Cochlearia officinalis—Scurvy-grass	Fresh plant—Gutret	Fresh plant, extract — Gutret, Tordeux	Yields oil of mustard.
Erysimum alliaria—Sauce alone	...	...	Myrosine, yields oil of mustard and oil of garlic (grown in sunny places only oil of mustard Pless)
Isatis tinctoria — Wood	Juice — Chevreul	Juice — Chevreul	Acetic acid, myrosine, white indigo.
Brassica Oleracea. β. viridis. Lin.	...	Juice of fresh plant—Schrader	
" " botrytis. Lin.	Juice — Tromsdorff	...	
" " Common sea cabbage	...	Juice—Sulliv.	Myrosine.
" rapa—White stone turnip	Juice—Sulliv.	Juice—Sulliv.	Myrosine, fat oil.
" campestris — Orange jelly	Juice—Sulliv.	Juice—Sulliv.	Myrosine, fat oil.
" Fettercairne green-top Swede	Juice—Sulliv.	Juice—Sulliv.	
" Skirving's purple-top	Juice—Sulliv.	Juice—Sulliv.	
" napus—Rape	Juice—Sulliv.	Juice—Sulliv.	Yields a sulphur oil, myrosine, fat oil.
Sinapis alba—White Mustard	Fresh plant—Sullivan	...	Citric and malic acids, Hydro-sulphocyanate of Sinapine, fat oil.
Raphanus sativus—Radish	...	Juice—Sulliv.	Acetic acid, myrosine, yields a sulphur oil, fat oil.
RESEDACEÆ. Reseda luteola—Weld	...	Fresh plant — Sullivan	Luteoline (non-nitrogenous), fat oil.
MALVACEÆ. Althaea officinalis—Marsh Mal-low	...	Fresh plant — Sullivan	Malic acid, asparagine; starch and mucilage.
TILIACEÆ. Tilia (Europæa ?)—Linden tree	Sap washed out of cambium; decoction of young twigs — Langlois	..	Acetic acid, malic acid, ? sugar, gum, gallic acid.
ACERACEÆ. Acer Pseudoplatanus — Syca-more	Sap in April—Sullivan	Sap in April—Sullivan	Fruit sugar (in descending sap), cane sugar.

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
SAPINDACEÆ. <i>Æsculus Hippocastanum</i> — <i>Horse-chestnut</i>	The young chestnuts with the pistils immediately after the falling off of the flower— <i>Vauquelin</i>	...	Acetic and oxalic acids, ? tannine, <i>Æsculine</i> , saponine, ? crystallizable bitter substance.
VITACEÆ OR AMPELIDEÆ. <i>Vitis vinifera</i> — <i>grape vine</i> .	Sap of vine drawn in March— <i>Langlois</i>	Sap of vine drawn in March— <i>Langlois</i>	Tartaric ( <i>racemic sometimes</i> ) and malic acids, lactic acid ( <i>in sap</i> , ? <i>Langlois</i> ) tannine, fruit sugar, fat oil.
OXALIDACEÆ. <i>Oxalis crassicaulis</i> " <i>Acetosella</i> — <i>Wood-sorrel</i>	Stems— <i>Payen</i> Fresh plant— <i>Sullivan</i>	... Fresh plant— <i>Sullivan</i>	Oxalic acid, Pectine.
TROPÆOLACEÆ. <i>Tropaeolum majus</i> — <i>Indian cress</i>	..	Fresh plant— <i>Sullivan</i>	Malic acid, a sulphuretted oil ( <i>allyle compound</i> ?)
XANTHOXYLACEÆ. <i>Xanthoxylon clava Herculis</i> — <i>Prickly ash</i>	Bark— <i>Chévalier</i> and <i>Pelletan</i>	..	Xanthopicroite ( <i>base</i> ?), acetic acid, tannine.
SIMARUBACEÆ. <i>Picrasma (Pieræna) excelsa</i> — <i>Bitter wood or common Quasia</i> <i>Simaruba amara</i> or <i>officinalis</i>	Wood— <i>Pfaff</i> Bark of root and lower part of trunk— <i>Morin</i> Ditto	Wood— <i>Pfaff</i> ... ..	Quassite. Malic acid, oxalic and acetic acids, Quassite.
" <i>Guianensis</i> LEGUMINOSÆ. a <i>Papilionaceæ</i> . <i>Cytisus (Sarthamnus) scoparius</i> — <i>common broom</i>	...	Fresh twigs macerated in water— <i>Sul.</i>	Sparteine ( <i>base</i> ), scoparine ( <i>coloury matter</i> ), both more abundant on sandy, sunny spots than when the vegetation is luxuriant upon shady ground— <i>Stenhouse</i> . malic acid.
<i>Dipterix odorata</i> — <i>Tonka-bean</i>	The Tonka bean <i>Boullay</i> and <i>Boutron-Charlard</i>	...	Malic acid, cumarine, sugar.
<i>Glycyrrhiza glabra</i> — <i>Liquorice</i>	Roots distilled with water— <i>Winkler</i>	...	Oxalic and malic acids, asparagine, glycyrrhizine, starch
<i>Robinia Pseudacacia</i> — <i>Locust tree</i>	Root— <i>Reinsch</i>	...	
<i>Vicia sativa</i> — <i>common vetch</i>	Young shoots— <i>Sullivan</i>	...	Pectine, asparagine ( <i>in young shoots</i> ). Legumine starch ( <i>in seeds</i> ).
<i>Phaseolus vulgaris</i> b <i>Cesalpinieæ</i> . <i>Cæsalpinia crista</i>	Young shoots— <i>Sullivan</i> Wood— <i>Chevreul</i>	... ...	Asparagine ( <i>in young shoots</i> ), starch ( <i>in seeds</i> ). Acetic acid.
<i>Hæmatoxylon capechianum</i> — <i>Logwood tree</i>	Wood— <i>Chevreul</i>	...	Acetic and oxalic acids, Hæmatoxyline.
ROSACEÆ. a <i>Amygdaleæ</i> . <i>Prunus Spinosa</i> — <i>Blackthorn</i>	Flowers and young twigs distilled with water— <i>Sullivan</i>	...	Malic and citric acids, tannine, amygdaline, phloridzine, gum, glucose, fat oil.

Plants examined arranged according to Orders,	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
<i>Prunus insititia</i> — <i>Bullace plum</i>	Fruit stone— <i>John</i>	...	Malic acid, amygdaline, phloridzine, gum, glucose, and fat oil.
<i>b Pomeæ.</i> <i>Pyrus Malus</i> — <i>Apple tree</i>	Sap in April— <i>Sullivan</i>	Sap in April— <i>Sullivan</i>	Malic, citric, and gallic acids, tannine, phloridzine, and probably valerate of oxide of amyle, glucose, pectine series.
" <i>communis</i> — <i>Pear tree</i>	Flowers yield Propylamine ( <i>Trimethylamine</i> )— <i>Wittstein</i>	...	Malic acid, some of the pectine series, phloridzine, glucose, amygdaline, acetate of oxide of amyle.
" ( <i>sorbus</i> ) <i>Ancuparia</i> — <i>Mountain ash</i>	Flowers distilled with water yield Propylamine ( <i>Trimethylamine</i> )— <i>Wittstein</i>	Sap— <i>Sullivan</i>	Tartaric, malic, and citric acids, sorbine, fermentable sugar ( <i>glucose</i> ), amygdaline.
<i>Cratægeus Oxyacantha</i> — <i>Oval berried hawthorn</i>	Flowers distilled with water give Propylamine ( <i>Trimethylamine</i> )— <i>Wicke</i>	...	Tannine, amygdaline, glucose.
CUCURBITACEÆ.			
<i>Ecballium purgans</i> (E. elaterium, Momordica Elaterium) — <i>Squirting cucumber</i>	...	Expressed juice— <i>Braconnot</i>	Elaterine ( <i>crystalline non-nitrogenous body</i> ), malic acid?
<i>Lagenaria vulgaris</i> — <i>Bottle gourd</i>	Pistil— <i>John</i>	Pistil— <i>John</i>	
<i>Cucumis sativus</i> — <i>Common Cucumber</i>	Green fruit— <i>John</i>	Green fruit— <i>Sullivan</i>	Tartaric acid ( <i>Strauch</i> ), malic acid, ? fat oil.
<i>Cucurbita Pepo</i> ( <i>Benincasa cerifera</i> )— <i>White gourd</i>	Flesh of fruit— <i>Braconnot</i>		
" <i>ovifera</i> — <i>Vegetable marrow</i>	Fruit— <i>Sullivan</i>	Fruit— <i>Sullivan</i>	
FICOIDEÆ.			
<i>Mesembryanthemum crystallinum</i> — <i>Ice plant</i>	...	Juice of plant and liquid of glands— <i>John</i>	Oxalic and malic acids.
GROSSULARIACEÆ.			
<i>Ribes Grossularia</i> — <i>Gooseberry</i>	...	Fruit— <i>Sullivan</i>	Malic and citric acids, sugar, gum.
SAXIFRAGACEÆ.			
<i>Saxifraga umbrosa</i> — <i>London pride</i>	...	Fresh plant— <i>Sullivan</i>	
UMBELLIFERÆ.			
<i>Apium graveolens</i> — <i>Celery</i>	Sap of young roots— <i>Lampadius</i>	Entire plant— <i>A. Vogel</i>	Apline, mannite.
<i>Conium maculatum</i> — <i>Hemlock</i>	Entire plant and seed	Juice of fresh leaves— <i>Schrader</i>	Malic and acetic acids, conine (base), methyleconine— <i>Keiske</i> and <i>V. Planta</i> .
<i>Ethusa cynapium</i> — <i>Fools parsley</i>	Fresh plant— <i>Sullivan</i>	Fresh plant— <i>Sullivan</i>	Cynapine (base ?).
<i>Foeniculum vulgare</i> — <i>Fennel</i>	Young shoots— <i>Sullivan</i>	Young shoots— <i>Sullivan</i>	Stearoptene of Anise ( <i>which yields hyduret of antisyle</i> ), acetic acid.
<i>Petroselinum sativum</i> — <i>Parsley</i>	Leaves— <i>Sul.</i>	Leaves— <i>Sul.</i>	Malic acid, apiline, essential oil ( <i>isomeric with oil of turpentine</i> ), sugar.
<i>Pastinaca sativa</i> — <i>Parsnip</i>	Root (also trimethylamine)— <i>Sullivan</i>	Root, alveole of leaves— <i>Sul.</i>	Pastinacine ( <i>volatile base</i> — <i>Wittstein</i> ), sugar.



Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
<i>Daucus carota</i> : <i>Common red carrot</i>	Root— <i>Sulliv.</i>	Root, alveole of leaves— <i>Sul.</i>	Malic acid, carotene (colouring matter), sugar, pectine series.
<i>Red Surrey</i> "	Root— <i>Sulliv.</i>	Leaves— <i>Sul.</i>	
<i>White Belgian</i> "	Root, leaves— <i>S</i>	Roots and leaves— <i>Sul.</i>	
CAPRIFOLIACEÆ.			
<i>Sambucus nigra</i> — <i>Common elder</i>	Flowers distilled with water— <i>Gleitsmann, Pagenstecher</i>	Bark— <i>Sulliv.</i>	Malic, acetic, and valerianic acids, grape sugar.
CINCHONACEÆ.			
<i>Cinchona Calysaya</i> var. vera.	Bark— <i>Reichardt.</i>	...	Quinine, quinidine, cinchonine, chinic, chinovic, and oxalic acids, pectine bodies, starch, tannine, etc.
" <i>micrantha</i>	Ditto Ditto	...	
" <i>ovata</i> var. <i>erythroderma</i>	Ditto Ditto	...	
" <i>cordifolia</i>	Ditto Ditto	...	
" <i>Condaminea</i> var. <i>lanceifolia</i> .	Ditto— <i>Reichel</i>	...	
COMPOSITÆ.			
<i>Cichorium Intybus</i> — <i>Chicory</i>	Root— <i>Juch</i>	Leaves— <i>Sul.</i>	Caoutchouc-like body, inuline.
" <i>Endivia</i> — <i>Endive</i>	Young plant— <i>S</i>	...	
<i>Lactuca virosa</i> — <i>Wild lettuce</i>	Milky sap or lactucarium— <i>Pagenstecher</i>	Leaves and stems at period of flowering — <i>Pagenstecher, Walz.</i>	Oxalic acid, valerianic acid ( <i>Ludwig</i> ), citric and malic acids ( <i>Walz</i> ), succinic acid, ( <i>Konke</i> ) lactucine ( <i>Amide?</i> ), lactucone.
		Lactucarium— <i>Pfaff &amp; Klink</i>	
" <i>sativa</i> — <i>Common lettuce</i>	At period of flowering distilled with water <i>Sullivan</i>	Extract of plant some years old— <i>Bley</i>	Malic, oxalic, and succinic acids. lactucine, lactucone.
" <i>altissima</i>	...	Milky sap— <i>Aubergier</i>	Malic and oxalic acids, asparagine, a crystallizable bitter substance, etc.
<i>Taraxacum officinale</i> ( <i>Leontodon Taraxacum</i> )— <i>Dandelion</i>	Juice— <i>Sulliv.</i>	Juice— <i>Sulliv.</i>	Taraxacine ( <i>bitter substance</i> ), inuline, caoutchouc-like body, mannite.
<i>Sonchus oleraceus</i> — <i>Common sow thistle</i>	Juice— <i>Sulliv.</i>	Leaves— <i>Sul.</i>	Caoutchouc-like body.
<i>Calendula officinalis</i> — <i>Marygold</i>	...	Leaves— <i>Geiger</i>	Malic acid, calenduline ( <i>mucilaginous substance</i> ).
<i>Cnicus benedictus</i> ( <i>Centaurea benedictus</i> )	...	Entire plant— <i>Morin</i>	Malic acid, cinicine ( <i>a bitter substance</i> ).
<i>Carduus</i> ( <i>Cnicus</i> ) <i>lanceolatus</i> — <i>Spear thistle</i>	..	Plant— <i>Sulliv.</i>	
<i>Senecio vulgaris</i> — <i>Groundsel</i>	Plant at period of flowering— <i>Sullivan</i>	...	
<i>Achillea millefolium</i> — <i>yarrow</i>	...	Entire plant, flowers— <i>Bley</i>	Propionic acid, achilleic ( <i>malic?</i> ) acid, achilleine ( <i>bitter substance</i> ).
" <i>nobilis</i>	Entire plant <i>Bley</i>	...	Formic, acetic, and malic acids, tannine.
<i>Matricaria Chamomilla</i> — <i>Common chamomile</i>	...	Extract— <i>Joss</i>	Tartaric acid (?), malic and acetic acids, essential oil.
<i>Artemisia Absinthium</i> — <i>Wormwood</i>	...	Watery extract— <i>Bracconot</i>	Succinic acid ( <i>probably also malic and santonic acids</i> ), absinthine ( <i>a bitter substance</i> ).

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
<i>Tanacetum vulgare</i> — <i>Tansey</i>	...	Fresh plant— <i>Sullivan</i>	Malic acid, tannine, gallic acid?, tanacetine (non-nitrog.), essential oil.
<i>Helianthus tuberosus</i> — <i>Girasole</i> ( <i>Jerusalem</i> ) <i>artichoke</i>	Young plant— <i>Sullivan</i>	Tubers— <i>Payen</i>	Citric and Malic acids ( <i>Bracconot</i> ), oxalic acid and trace of gallic ( <i>Payen</i> ), inuline, pectine, glucose.
<i>Helianthus annuus</i> — <i>Sunflower</i>	Young plant— <i>Sullivan</i>	Pith of stalk— <i>John</i>	Malic acid, asparagine ( <i>earliest period of development</i> ), inuline, fat oil.
<i>Dahlia variabilis</i> — <i>Dahlia</i>	Tubers— <i>Payen</i>	Tubers— <i>Payen</i>	Citric and malic acids, asparagine (in the germs of the tubers when grown in the dark), inuline, etherial oil.
STYRACACEÆ.			
<i>Styrax officinale</i>	Storax— <i>Reinsch</i>	..	Benzoic acid and essential oil.
AQUIFOLIACEÆ.			
<i>Ilex aquifolium</i> — <i>Holly</i>	Bark and flowers— <i>Sulliv</i>	...	Illicine (non-nitrogenous?).
OLEACEÆ.			
<i>Fraxinus excelsior</i> — <i>Ash</i>	Sap in April— <i>Sullivan</i>	Sap in April— <i>Sullivan</i>	Mannite, crystallizable bitter substance ( <i>fraxinine</i> ).
ASCLEPIADACEÆ.			
<i>Cyanchum vincetoxicum</i>	Root <i>Feneulle</i>	...	Malic and oxalic acids.
GENTIANACEÆ.			
<i>Menyanthes trifoliata</i> — <i>Bogbean</i>	Young plant— <i>Sullivan</i>	...	Malic and acetic acids, inuline, menyanthine (a bitter substance).
CONVOLVULACEÆ.			
<i>Convolvulus arvensis</i>	Plant— <i>Chevalier</i>	...	Malic and acetic acids.
<i>Batatas</i> ( <i>Batatas edulis</i> )— <i>sweet potato</i>	Fresh root of variety, with rose-coloured rind— <i>Payen and O. Henry</i>	..	Malic and oxalic acids, starch, sugar.
<i>Convolvulus sepium</i> ( <i>calystegia sepium</i> )— <i>Great Bindweed</i>	Plant— <i>Chevalier</i>	...	Malic and acetic acids.
BORAGINACEÆ.			
<i>Anchusa tinctoria</i> — <i>Alkanet</i>	Root— <i>Bolley &amp; Wydler</i>	...	Tannine? anchusine (a bitter substance).
<i>Borago officinalis</i>	Watery extract of entire fresh flowering plant— <i>Lampadius</i>	Watery extract of entire fresh flowering plant— <i>Lampadius</i>	Acetic acid.
SOLANACEÆ.			
<i>Solanum tuberosum</i> — <i>Potato</i>	Tubers, buds, leaves, fruit— <i>Sullivan</i>	Leaves— <i>Sulliv.</i>	Malic and tartaric acids, solanine, starch.
<i>dulcamara</i> — <i>Bitter-sweet</i>	Leaves and stalks and fruit— <i>Sulliv.</i>	...	Malic acid, solanine.
<i>nigrum</i>	Leaves and fruit	...	Malic acid, solanine.
<i>verbascofolium</i>	Fruit and Stalks— <i>Payen and Chevallier</i>	...	Malic acid, solanine.
<i>Lycopersicon esculentum</i> — <i>Tomato</i>	Fruit— <i>Sulliv.</i>	..	Oxalic acid.

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
ATROPACEÆ.			
<i>Atropa Belladonna</i> — <i>Deadly nightshade</i>	Expressed juice, entire plant— <i>Vauquelin, Brandes</i>	Expressed juice, entire plant— <i>Vauquelin, Brandes</i>	Malic, oxalic, and acetic (?) acids, fat oil, atropine, asparagine, esculine? ( <i>a one year old extract of the leaves also contained asparagine</i> ).
<i>Datura Stramonium</i> — <i>Thorn-apple</i>	...	Fresh plant, extr. some yrs. old— <i>Promnitz, Bley</i>	Malic and acetic acids, atropine, sometimes stramonine.
<i>Hyoscyamus niger</i> — <i>Henbane</i>	...	...	Malic and acetic acids, hyoscyamine.
<i>Nicotiana Tabacum</i> — <i>Virginian Tobacco</i>	Juice of leaves, etc.— <i>Vauquelin, Reimann, and Posselt</i>	Juice of fresh leaves— <i>Vauquelin, Reimann, and Posselt</i>	Malic and citric acids ( <i>acetic acid?</i> ) nicotine, nicotianine, methylenicotine, (?) fat oil.
<i>Nicotiana rustica</i> — <i>Syrian Tobacco</i>	Fresh leaves, flowers— <i>Sullivan</i>	Fresh leaves— <i>Sullivan</i>	
LABIATÆ.			
<i>Salvia officinalis</i> — <i>Sage</i>	...	Plant— <i>Ilisch</i>	Malic acid, tannine.
<i>Lamium purpureum</i>	...	Juice of fresh plant— <i>John</i>	Malic acid.
<i>Leonurus lanatus</i> ( <i>Ballota lanata</i> — <i>Lin.</i> )	...	Plant— <i>Jori</i>	Tannine.
PLANTAGINACEÆ.			
<i>Plantago lanceolata</i> — <i>Ribwort</i>	...	Leaves— <i>Sul.</i>	
CHENOPODIACEÆ.			
<i>Beta maritima</i> — <i>Sea-beet</i>	...	...	Oxalic acid.
„ <i>vulgaris</i> $\beta$ <i>cicla</i> — <i>Lin.</i> :	Root, crown, etc.— <i>Buchner, Payen</i>	Root, crown— <i>Buchner and Payen</i>	Citric and oxalic acids, pectase and pectose, sugar.
White Silesian	Root, alveoles, leaves— <i>Sul.</i>	Root, alveoles, leaves— <i>Sul.</i>	
Long, red mangel wurzel	Ditto— <i>Sulliv.</i>	Ditto— <i>Sulliv.</i>	
Yellow globe „	Ditto— <i>Sulliv.</i>	Ditto— <i>Sulliv.</i>	
Orange „	Ditto— <i>Sulliv.</i>	Ditto— <i>Sulliv.</i>	
Red „	Ditto— <i>Sulliv.</i>	Ditto— <i>Sulliv.</i>	
<i>Chenopodium</i> ( <i>Ambrina</i> ), <i>ambrosioides</i>	...	Plant— <i>Bley</i>	
„ <i>Vulvaria</i> ( <i>olidum</i> )	The plant exhales ammonia <i>Chevalier</i> , and propylamine— <i>Dessaignes</i>	...	Acetic acid. (Part of the ammonia exhaled is combined with acetic acid).
„ hybridum	Plant yields ammonia when distilled with water— <i>Sul.</i>	...	Malic and oxalic acids, starch, tannine.
POLYGONACEÆ.			
<i>Rheum raphonticum</i> — <i>Rhubarb</i>	Stalks and leaves— <i>Sul.</i>	Stalks and leaves— <i>Sul.</i>	
<i>Rumex obtusifolius</i> — <i>Dock</i>	Leaves— <i>Sul.</i>	Leaves— <i>Sul.</i>	Oxalic and malic acids ( <i>probably also tartaric</i> ), chrysophanic acid ( <i>rumicine</i> ), tannine.
„ <i>Acetosella</i> — <i>Sheep's sorrel</i>	Leaves— <i>Sul.</i>	Leaves— <i>Sul.</i>	Oxalic and tartaric acids.
<i>Polygonum tinctorium</i>	...	Leaves— <i>Girardin and Preisser</i>	Oxalic acid ( <i>Hervy</i> ), acetic and malic acids ( <i>Girardin and Preisser</i> ), indigo, tannine.



Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric Acid.	
ARISTOLOCHACEÆ. <i>Aristolochia Clematidis</i>	Root	Root— <i>Frickinger</i>	Malic acid, tannine, bitter substance.
<i>Asarum europæum</i>	Plant— <i>Las-saigne and Feneulle.</i>	...	Acetic, citric, and malic acids, tannine, asarone ( <i>non-nitrog.</i> ).
EUPHORBACEÆ. <i>Hura crepitans</i> — <i>Sandbox tree</i>	...	Milky sap— <i>Boussingault and Rivero</i>	Malic acid, tannine, gallic acid, acid crystallizable substance ( <i>hurine</i> ) caoutchouc-like body.
<i>Euphorbia hiberna</i> — <i>Irish spurge</i>	Fresh plant— <i>Sullivan</i>	...	Euphorbine ( <i>base</i> ?).
URTICACEÆ. <i>Urtica dioica</i> — <i>Nettle</i>	Waterydistillat from plant— <i>Bohlig</i>	...	Formic, acetic, malic, and oxalic acids.
<i>Cannabis sativa</i> — <i>Hemp</i>	Leaves, pollen— <i>Tscheppe, John</i>	Leaves— <i>Tscheppe</i>	Acetic and malic acids, fat oil ( <i>containing an alkaloid according to Gastinell</i> ), cannabine ( <i>resin</i> ).
<i>Humulus Lupulus</i> — <i>Hop</i>	Leaves, leaf-stalks, bark of roots and stems, male flowers, bracts, lupuline— <i>Payen, Pelletan, and Chevallier</i>	Leaves, leaf-stalks, bark of roots and stems, male flowers, bracts— <i>Payen, Pelletan, and Chevallier</i>	Acetic and malic acids, tannin, asparagine, essential oil ( <i>an oil isomeric with oil of turpentine and valerol</i> ), lupuline ( <i>bitter substance</i> ).
ULMACEÆ. <i>Ulmus campestris</i> — <i>Elm</i>	...	...	
PIPERACEÆ. <i>Cubeba officinalis</i>	Fruit— <i>Vauquelin</i>	...	Acetic acid, tannine, mucus.
<i>Pothomorphe umbellata</i>	...	Root— <i>N. E. Henry</i>	Malic and acetic acids, cubebine ( <i>non-nitrogenous</i> ), oil of cubebs ( <i>isomeric with oil of turpentine</i> ).
SALICACEÆ. <i>Salix viminalis</i> — <i>Common osier</i>	Young green twigs and buds— <i>Sul.</i>	Green twigs and buds— <i>Sullivan</i>	Tannine, salicine. ?
<i>Populus nigra</i> — <i>Black poplar</i>	Fresh buds— <i>Pellerin</i>	...	Tannine ( <i>gallic acid</i> ), malic acid, salicine, populine, ? essential oil.
BETULACEÆ. <i>Betula alba</i> — <i>Common birch</i>	Sap in April— <i>Sullivan</i>	Sap in April— <i>Sullivan</i>	Acetic and probably tartaric acids, sugar, fruit sugar ( <i>in ascending sap</i> ), tannine, betuline, ( <i>a crystallizable resin</i> ).
<i>Alnus glutinosa</i> — <i>Alder</i>	Sap in April— <i>Sullivan</i>	...	Tannine.
CORYLACEÆ OR CAPULIFERÆ. <i>Castanea vulgaris</i> — <i>Spanish chestnut.</i>	...	Sap— <i>Vauquelin</i>	Acetic acid, sugar, starch.
<i>Corylus Avellana</i> — <i>Hazel</i>	...	Sap— <i>Sullivan</i>	Malic acid, ? fat oil.
<i>Fagus sylvatica</i> — <i>Beech</i>	Sap in April— <i>Sullivan</i>	Sap in April— <i>Sullivan</i>	Acetic acid, tannine ( <i>gallic acid</i> ), fagine ( <i>a volatile base</i> ), fat oil.
JUGLANDACEÆ. <i>Juglans regia</i> — <i>Walnut-tree</i>	Sap in April— <i>Langlois</i>	Sap in April— <i>Langlois</i>	Lactic acid (? <i>Langlois</i> ), acetic, malic, and oxalic acids, fat oil, tannine, juglandine ( <i>non-nitrogenous</i> ).

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric Acid.	
CONIFERÆ.			
<i>Pinus sylvestris</i> — <i>Scotch fir</i> .	Pollen— <i>John</i>	...	Formic and citric acids, tannine, pimaric acid, fat oil, oil of turpentine, pinipicrine ( <i>bitter substance</i> ).
" <i>abies</i>	Pollen— <i>John</i>	...	Formic and malic (?) acids, tannine, pimaric acid, fat oil, oil of turpentine.
ZINGIBERACEÆ OR SCITAMINEÆ.			
<i>Alpinia Galanga</i>	Water distilled from root— <i>A. Vogel, jun.</i>	...	Oxalic and acetic acids, gum, Kœmpferide ( <i>non-nitrogenous</i> ).
MUSACEÆ.			
<i>Musa paradisiaca</i> — <i>Plantain</i>	...	Sap— <i>Fourcroy and Vauquelin</i>	Acetic, oxalic, malic, and gallic acids, tannine, sugar ( <i>starch in unripe fruit</i> ).
<i>Musa rosacea</i>	Expressed juice of stem— <i>Clamor Marquart</i>	...	Malic and acetic acids, tannine, sugar
AMARYLLIDACEÆ.			
<i>Agave americana</i>	...	Expressed juice— <i>Sul.</i>	
LILIACEÆ.			
<i>a Asphodelææ.</i>			
<i>Allium Ceba</i> — <i>Onion</i>	Young plant— <i>Sullivan</i>	...	Acetic (?) and citric acids, pectic acid, tannine ( <i>in Autumn</i> ), sugar, sulphide of allyle.
<i>Allium sativum</i> — <i>Garlic</i>	Bulbs— <i>Sulliv.</i>	...	Sulphide of allyle.
" <i>Porrum</i> — <i>Leek</i>	Young plant— <i>Sullivan</i>	...	
<i>b Smilacææ.</i>			
<i>Asparagus officinalis</i> — <i>Asparagus</i>	Young shoots— <i>Sullivan</i>	Young shoots— <i>Sullivan</i>	Malic and acetic acids, asparagine.
PALMÆ.			
<i>Areca Catechu</i>	Fruit— <i>Morin</i>	...	Oxalic, acetic, and gallic acids, tannine, starch (in pith).
GRAMINEÆ.			
<i>Triticum vulgare</i> — <i>var. hybernum</i> — <i>Winter wheat</i>	Very young plants— <i>Sul.</i>	...	Mannite, oxalic acid, glucose, starch
<i>Saccharum officinarum</i> — <i>Sugarcane</i>	...	Juice of cane— <i>Sullivan</i>	Oxalic, acetic, and malic acids, sugar, wax.
LICHENES.			
<i>Cetraria islandica</i> — <i>Iceland moss</i>	Plant— <i>John</i>	Plant— <i>John</i>	Fumaric, cetraric, and Lichenstearic acids, substances capable of being transformed into sugar ( <i>lichen starch, etc.</i> )
<i>Sticta pulmonaria</i>	Plant— <i>John</i>	...	Lichen starch, probably cetraric acid or some analogous body.
<i>Parmelia ciliaris</i>	Plant— <i>John</i>	...	Lichen starch.
FUNGI.			
<i>Agaricus campestris</i> — <i>Common mushroom</i>	Plant— <i>Gobley—Sullivan</i>	...	Probably lichenstearic acid, fumaric, malic, and citric acids, mannite.
<i>Agaricus stercorearius</i> — <i>Dung agaric</i>	Plant— <i>Sulliv.</i>	...	
<i>Boletus Grevillei</i> — <i>Yellow boletus</i>	Plant— <i>Sulliv.</i>	...	Oxalic acid.
<i>Exidia glandulosa</i> — <i>Witches' butter</i>	Plant— <i>Sulliv.</i>	...	
<i>Phallus impudicus</i> — <i>Common stinkhorn</i>	Plant— <i>Brannon</i>	...	Acetic acid, mannite.
<i>Lycoperdon pusillum</i> — <i>Dwarf puffball</i>	Plant— <i>Sulliv.</i>	...	

Plants examined arranged according to Orders.	Parts of Plant used.		Acids, bases, etc., which occur in each plant.
	Ammonia.	Nitric acid.	
<i>Lycoperdon gemmatum</i> — <i>Stud-</i> <i>ded puffball</i>	Plant— <i>Sulliv.</i>	...	
<i>Elaphomyces granulatus</i>	Seed, peridium of the warty kind— <i>Biltz</i>	...	Mannite.
<i>Helvella esculenta</i>	Plant— <i>Schra-</i> <i>der</i>	...	Fumaric, citric, malic, and lactic acids, mannite.
<i>Peziza vesiculosa</i>	Plant— <i>Sulliv.</i>	...	
<i>Tuber cibarium</i> — <i>Truffle</i>	Plant— <i>Riegel</i>	...	Fumaric, citric, and malic acids, mannite.
<i>Sphacelia segetum</i> — <i>Ergot of rye</i>	Yields a vo- latile alkali when dis- tilled with water and potash— <i>Winkler</i> . This is also probably tri methyla- mine.	...	According to Dr. Lévillé, ergot of rye consists not merely of the small parasite, <i>sphacelia segetum</i> , but also of grain altered in its chemical composition.